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II (12)

CONDITION SURVEY OF POROUS FRICTION SURFACE COURSE

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FINAL REPORT

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16. Abstract

The objectives of this report are to identify performance problems observed with the porous friction course (PFC) and to evaluate the effectiveness of the current maintenance and repair practices used. Ten airports, seven commercial and three military, with existing PFC runways were selected for the survey. These PFC airport pavements were built with various materials and construction techniques and had been in place for various lengths of time. The seven commercial airports evaluated are also included in the Federal Aviation Administration National Runway Friction Measurement Program. Conversations with airport personnel, local engineers, and other knowledgeable sources provided information on mix design, construction procedures, and performance problems. Based on the survey, the performance problems were identified and maintenance procedures to correct these problems were investigated.

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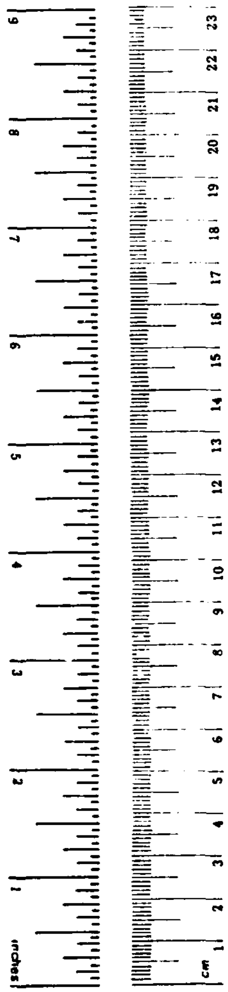
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

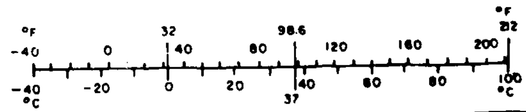
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This project was conducted during the period August 1979 to June 1980 by the Pavement Systems Division (PSD) of the Geotechnical Laboratory (GL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, for the U. S. Department of Transportation, Federal Aviation Administration, Systems Research and Development Service, as part of the Inter-Agency Agreement No. DOT FA79WAI-027, "Rehabilitation of Porous Friction Courses."

The project was performed under the general supervision of Mr. James P. Sale, former Chief of GL, and Dr. Don C. Banks, Acting Chief of GL, and under the direct supervision of Messrs. Alfred H. Joseph, Chief of PSD, and Elton R. Brown, Chief of Material Research Center (PSD). This report was prepared by Mr. James E. Shoenberger.

COL Nelson P. Conover, CE, was Commander and Director of the WES during the period of the project and the preparation of this report. Technical Director was Mr. Fred R. Brown.

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INTRODUCTION

BACKGROUND

The porous friction course mix, also known as "open-graded mix," "plant-mix seal coat," and "popcorn mix," is referred to by the abbreviation "PFC" throughout this report. A PFC is an open-graded, free-draining, bituminous mixture that is used as a means of preventing hydroplaning and improving traction on wet pavements.

Although the PFC has been used in England since the late 1950's, its introduction in the United States in the late 1960's resulted in the construction of increasing numbers of PFC pavements. Many of the PFC pavements have now reached an age where maintenance is becoming a problem. This increase in use and age has brought to light the need for airport operators to be able to estimate the service life of the PFC pavements and to determine satisfactory maintenance procedures to correct the various problems that occur in PFC pavements.

Engineers on a number of airfields that have PFC pavements are faced with increasing maintenance problems. Some of the problems include crack sealing, patching, and the overlaying of PFC's. Conventional maintenance techniques that have been used for dense-graded asphaltic concrete pavements in the past may not be satisfactory for use with PFC pavements.

OBJECTIVES

The service life of a PFC is affected by the environment, underlying pavement condition, traffic, design, and construction materials. Problems that may be associated with PFC performance include raveling, cracking, and loss of permeability. The objectives of this study are (a) to identify problems that have been observed in the performance of PFC pavements and (b) to evaluate the effectiveness of current maintenance and repair practices used to correct the problems identified.

SCOPE

A number of airfields with existing PFC pavements were selected to be inspected to determine performance problems and maintenance techniques being used to correct these problems. These airfields were located in the various climatic regions of the United States so that the effect of the environment could be determined. These PFC pavements were designed using a number of design procedures and built with various materials and construction techniques.

Criteria used in selecting the PFC airport pavements surveyed for this report included selection of those PFC pavements that had been in place the longest and those that had been subjected to some type of maintenance. Another requirement for the selection of commercial airports was that the airport be included in the Federal Aviation Administration (FAA) National Runway Friction Measurement Program.

Condition surveys were conducted on selected PFC pavements at 10 different airports throughout the United States. Three of the airfields were military airbases, and the remaining seven were civilian airports. Table 1 lists the airports surveyed and the date of each survey.

Table 1. Airport Locations and Dates Surveyed

Site No.	Location	Date Conducted
1	Great Falls International Airport, Great Falls, Montana	Apr 80
2	Greensboro-High Point-Winston Salem Airport, Greensboro, North Carolina	Jan 80
3	Monroe Regional Airport, Monroe, Louisiana	Apr 80
4	Dallas Naval Air Station, Dallas, Texas	May 80
5	Pease Air Force Base, Portsmouth, New Hampshire	Jan 80
6	Portland International Airport, Portland, Maine	Jan 80
7	Salt Lake City International Airport, Salt Lake City, Utah	Apr 80
8	Scott Air Force Base, Illinois	May 80
9	Sioux City Municipal Airport, Sioux City, Iowa	May 80
10	Joe Foss Field, Sioux Falls, South Dakota	May 80

PFC TESTS

PERMEABILITY

Field and laboratory permeability tests run on the PFC's followed test procedures presented in Appendix A. Table 2 summarizes the results of the tests. One series included running three permeability tests both in and out of the trafficked area. These tests were averaged to obtain one value both in and out of traffic. It was found that the permeabilities obtained were generally well above 1000 ml/min, generally considered as an acceptable minimum limit.[1] The PFC from Portland International Airport, however, provided an average permeability both in and out of traffic less than the desired 1000 ml/min.

FIELD SAMPLES

Core specimens were taken in order to run extractions and gradations to verify the construction data. Where core specimens were not obtained, data were generally available from previous testing.[1,2] Scheduling difficulties prohibited sampling at Scott Air Force Base and on runway 3-21 at Great Falls Airport. Table 2 lists the asphalt content and aggregate gradations determined from the latest available test data.

Table 2. Porous Friction Course Evaluation

Site No.	Location	Runway No.	Date Surveyed	Traffic Area	Asphalt Content Percent*	Percent Aggregate Passing Cited Sieve Size: 3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	Flow Rate for Falling Head Permeability ml/min**: Field	Laboratory
1	Great Falls	16-34	Apr 80	In	6.7	100.0	100.0	95.1	39.4	18.9	12.6	--	8.0	--	4.2	1244	
			Mar 75†	Out	5.8	100.0	100.0	95.9	45.2	20.5	12.5	--	7.5	--	4.4	2205	
		3-21	Apr 80	In	NO CORES TAKEN											3136	
				Out												3992	
2	Greensboro	14-32	Jan 80	In	6.0	100.0	100.0	98.1	49.5	19.0	10.5	--	4.8	--	2.7	1890	
			Mar 75†	Out	6.2											2988	
3	Monroe	4-22	Apr 80	In												1734	
				Out	4.7	99.0	90.7	74.6	34.2	18.7	12.0	8.7	6.5	5.0	3.8	2969	
4	Dallas Naval	17-35	May 80	In	5.3	100.0	100.0	100.0	37.1	13.3	6.1	--	3.0	--	2.1	2337	
	Air Station		Apr 75†	Out	5.0	100.0	100.0	100.0	47.7	19.6	7.9	--	3.5	--	1.9	4169	
5	Pease Air	--	Jan 80	In	4.9	100.0	100.0	94.8	40.2	22.2	14.4	--	7.6	--	4.5		1276
	Force Base		Mar 75†	Out	5.2												
6	Portland	--	Jan 80	In	6.4	100.0	100.0	100.0	50.1	24.9	17.2	13.5	10.1	7.0	4.5		864
				Out	6.2	100.0	100.0	99.7	50.7	24.8	16.7	12.9	8.1	5.4	3.6		639
7	Salt Lake City	16L-34R	Apr 80	In	4.6	100.0	87.7	69.7	32.9	16.5	10.5	--	5.5	--	3.1	1028	
		Parallel															
		taxiway	Mar 75†	Out	4.7	100.0	92.3	72.1	32.0	16.8	11.7	--	5.9	--	3.0	1028	
		16L-34R	Apr 80	In	NO CORES TAKEN											1037	
				Out												1203	
8	Scott Air	--	May 80	In	NO CORES TAKEN											858	
	Force Base			Out												1403	
9	Sioux City	13-31	May 80	In	5.6	100.0	100.0	90.4	36.4	15.7	10.6	9.1	6.8	4.9	3.8	2857	
				Out	5.4	100.0	100.0	91.7	37.5	15.7	10.5	8.9	6.7	4.7	3.6	2373	
10	Sioux Falls	15-33	May 80	In	5.9	100.0	94.9	74.0	28.5	15.4	11.1	9.8	8.5	5.5	3.6	2173	
				Out	6.6	100.0	89.5	68.9	28.3	15.7	12.2	11.0	9.6	6.4	4.1	2755	

Note: 1 in. = 2.54 cm.
* Based on amount extracted from field core.
** All permeability measurements were made in 1980.
† Date of sampling for gradation and asphalt content.

FIELD SURVEYS

A visual inspection was made of the PFC pavement at each location. When airports had more than one PFC, each PFC was visually inspected whenever possible. Table 2 lists the results of field and laboratory tests for the PFC's surveyed. Table 3 lists construction data, traffic data, and the latest friction measurement values when available.

Permeability tests were conducted on all PFC's surveyed. The tests on the PFC from Pease Air Force Base and Portland International Airport were conducted in the laboratory on cored samples with the remaining airports being tested in the field. The field tests were conducted in areas, both in and out of traffic, with sample locations randomly selected to represent the entire PFC. The areas selected for testing were relatively free of foreign materials (paint, rubber build-up, etc.) and most structural defects (cracking, raveling, etc.).

GREAT FALLS INTERNATIONAL AIRPORT

A condition survey of PFC runways 16-34 and 3-21 at Great Falls Airport was conducted in April 1980. Permeability tests were conducted on both runways.

The 3/4-in.- (19.05-mm-) thick PFC on runway 16-34 was constructed in September 1972. From 1972 to 1978, runway 16-34 was trafficked by both private and air carrier aircraft; since 1978, it has been used only by occasional private aircraft. The PFC mix design was determined using the Marshall mix method. The initial asphalt content selected was at 7.5 percent but was lowered to 7.0 percent when excess drainage was noted during construction of a test section. The need to adjust the asphalt content could be expected since the Marshall[3] mix design method was developed for dense-graded mixtures. A 60-70 penetration (pen) grade asphalt was selected for use on this job. Silicon was added to the asphalt to improve its antistripping properties. The gradation of the aggregate was within the recommended Federal Aviation Administration (FAA) gradation limits given in Standard Qualification

Table 3. PFC Construction Data

Site No.	Location	Runway No.	Date Constructed	PFC Thickness in.	Basis for Selecting PFC Job-Mix Design: Method	Basis for Selecting PFC Job-Mix Design: Condition	Asphalt Cement Data: Penetration 1/10 mm	Asphalt Cement Data: Asphalt Content percent	Percent Aggregate Passing Cited Sieve Size: 3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 200
1	Great Falls	16-34	1972	3/4	Marshall, test section	Varied asphalt content	60-70	7.0*	100	100	90	35	15	10	--	--	-
		3-21	1978	3/4	Experience, test section	Varied asphalt content	85-100	7.2	100	91	67	28	16	12	--	--	2
2	Greensboro	14-32	1975	3/4	$2K_c + 4.0$, test section	Varied asphalt content	85-100	6.5	100	100	97	38	15.7	--	--	4	2
3	Monroe	4-22	1974	1	Five test sections	Varied asphalt content	85-100	5.0	100	78	48	26	17	--	8	--	[illegible]
4	Dallas Naval Air Station	17-35	1971	5/8	Test section	Varied asphalt content	47	6.5	100	100	97	52	5.3**	--	--	--	--
		17-35 Extension	1977	5/8-3/4	Test section	Varied asphalt content	60-70	6.1	100	100	91	33	17**	--	--	--	3
5	Pease Air Force Base	--	1972	1	Test section	Varied asphalt content	120-150	5.2	100	100	92	35	21	--	--	--	3
6	Portland	--	1973	3/4	Marshall	--	82-85	6.5	100	100	98	41	20	--	9	--	2
7	Salt Lake City	16L-34R	1972	3/4	Test section	Varied asphalt content	60-70	5.75	100	97	75	35	15	12	--	8	4
8	Scott Air Force Base	--	1976	3/4	$2K_c + 4.0$	--	85-100	6.5	100	93	78	37	19	13	--	--	4
9	Sioux City	13-31	1974	3/4	Test section	Varied asphalt content	85	6.0	100	100	85.0	23.5	11.9	--	7.6	--	2.9
		17-35	1977	1	Test section	Varied asphalt content	60-70	6.0	100	99.5	84.3	26.6	15.5	--	8.5	--	3.8
10	Sioux Falls	15-33	1979+	3/4	$2K_c + 4.0$	--	85-100	7.5	100	85	72	27	14	6	--	--	3.5

(Continued)

Note: 1 in. = 2.54 cm; 1 oz = 24.35 g ; 1 gal = 3.79 cu dm; 1°F = -17°C; 1 gal/sq yd = 4.53 cu dm/sq m.
* Decreased asphalt content from 7.5 to 7.0 after excess drainage was noted.
** Sieve designation No. 10.
\+ Overlaid one PFC with another.

(Sheet 1 of 3)

Table 3 (Continued)

Site No.	Location	Runway No.	Additives	Aggregate Characteristics: Type	Specific Gravity	Abrasion percent	Soundness percent	Mixing Data: Mixing Temp °F	Viscosity at Mixing, cSt	Remarks	Seasonal Weather Condition	Average Mu-Meter Reading dry/wet
1	Great Falls	16-34	Silicon for antistrip	Limestone	2.68	22	--	285	--	Asphalt drainage	20-30 freeze-thaw cycles	79/78 78/71
		3-21	1-2 percent neoprene rubber	Limestone	--	--	--	300	--	--	--	
2	Greensboro	14-32	1.5 percent neoprene rubber	Granite	2.82	24	1.7	280	270	No asphalt drainage	--	In 81/76 Out 80/89
3	Monroe	4-22	None	Chert	2.7	23.7	--	250	--	--	--	--
4	Dallas Naval Air Station	17-35	None	Basalt	--	15.4	--	240	--	--	--	--
		17-35 Extension	1.5-2.0 percent hydrated lime	Basalt	--	--	--	260++	--	--	--	
5	Pease Air Force Base	--	1.5 percent hydrated lime	Basalt	2.76	13.5	10	250	--	No asphalt drainage	--	--
6	Portland	--	None	Ledge rock	2.69	--	--	300	485# 409#	No asphalt drainage	--	--
7	Salt Lake City	16L-34R	1.5 percent neoprene rubber	Slag	3.75	12-15	--	325	185	Asphalt drainage	100 freeze-thaw cycles	--
8	Scott Air Force Base	--	1.5 percent neoprene rubber 1.5 percent hydrated lime	Felsite	2.77	18.2	--	300	--	--	--	--
9	Sioux City	13-31	None	Quartzite	2.68	21	0.8	265##	--	--	--	>90
		17-35	None	Quartzite	--	--	--	265##	--	--	--	>90
10	Sioux Falls	15-33	1.5 percent neoprene rubber 1-oz silicon for 5000-gal asphalt	Quartzite	2.65	--	--	300	--	--	--	In 80/79 Out 80/78

(Continued)

++ Maximum mixing temperature, from specifications.
\# Two sources of asphalt at 275°F.
\## Temperature at placement.

(Sheet 2 of 3)

Table 3 (Concluded)

Site No.	Location	Runway No.	Construction: Contractor	Mixing Equipment	Placement Equipment	Rolling Procedures	Conformance to Specifications	Tack Coat: Type	Tack Coat: Quantity gal/sq yd	Type of Aircraft Using Airport	Flights/Year of Commercial Carriers (approximate)
1	Great Falls	16-34	--	Batch plant	Paver	Steel-wheel roller	--	SS-1h	0.05	Private, air carrier	Restricted since 1978
		3-21	Thomas, Dean, Hasgins, Mont.	Batch plant	Paver	Steel-wheel roller	North Testing Lab, Great Falls, Mont.	--	--		
2	Greensboro	14-32	Thompson-Arthur, N. C.	Batch plant	Paver	Two steel-wheel rollers	Pittsburgh Testing Lab, N. C.	--	--	Private, air carrier	6,500
3	Monroe	4-22	Jenkins, Lazenby, and Associates, La.	Batch plant	Paver	Steel-wheel roller	Shilstone Testing Lab, La.	--	--	Private, air carrier	4,300
4	Dallas Naval Air Station	17-35	Uvalde Construction Co., Tex.	Batch plant	Paver	Three passes with a 10-ton steel-wheel roller, pneumatic rolling when cooled	--	RS-1	0.1	Jet fighters, military transports	--
		17-35 Extension	Uvalde Construction Co., Tex.	Batch plant	Paver	Three passes with a 10-ton steel-wheel roller, pneumatic rolling when cooled	Southwestern Lab, Tex.	RS-1	--		
5	Pease Air Force Base	--	Iafola Construction Co., Portsmouth, N. H.	Batch plant	Paver	Four passes maximum with a steel-wheel roller	Pease Air Force Base	--	--	Jet fighters, military tankers and transports	--
6	Portland	--	Blue Rock Industries, Maine	Batch plant	Paver	Steel-wheel roller	Maine Department of Transportation	--	--	Private, air carrier	--
7	Salt Lake City	16L-34R	Gibbons and Reed Construction Co., Utah	Batch plant	Paver	Steel-wheel roller	Airport Engineer	--	--	Private, air carrier	--
8	Scott Air Force Base	--	Thacker Construction Co., Ill.	Cont. mix plant	Paver	Two to four passes with a steel-wheel roller	U. S. Army Engineer District, Omaha, Nebr.	SS-1h §	0.05	Jet fighters, military transports	--
9	Sioux City	13-31	Brower Construction Co., Iowa	Batch plant	Paver	Steel-wheel roller	Midwest Testing Lab, Iowa	--	--	Private, air carrier	4,200 4,200
		17-35	Brower Construction Co., Iowa	Batch plant	Paver	Steel-wheel roller	Midwest Testing Lab, Iowa	--	--		
10	Sioux Falls	15-33	Myrl and Roy's Paving Co., Sioux Falls, S. Dak.	Batch plant	Paver	Four passes with a steel-wheel roller	Schmitz-Kalda and Associates, Sioux Falls, S. Dak.	--	0.1	Private, air carrier	15,000

Note: Most civilian airports receive a minor amount of traffic from military planes because of Air Force or National Guard units.
§ Rolled tack coat with pneumatic roller.

(Sheet 3 of 3)

Section P-402.[4] The aggregate consisted of crushed limestone with a specific gravity[5] of 2.68 and a Los Angeles abrasion test[6] value of 22 percent. The mixing temperature selected was 285°F (141°C). The PFC mixture was produced in a batch plant and then placed with a conventional 12-ft- (3.66-m-) wide paver. Rolling to properly seat the PFC was accomplished with a steel-wheel roller. A light tack coat was applied to the underlying pavement.

The winter following construction was moderate, but numerous popouts (the loss of singular pieces of surface aggregate) were observed after the first winter that were attributed to freeze-thaw cycles. Normally 20-30 freeze-thaw cycles occur per year in this area. Extensive reflective cracks, which run the entire width of the runway, appeared through the PFC several months after construction. These cracks were sealed in 1974 with a mixture of SS-1h emulsion and sand to control raveling adjacent to the cracks (Figure 1). According to local engineers, some longitudinal paving joints contained depressions or ridges, which were caused by both cool weather conditions and poor construction procedures such as overlapping some longitudinal joints and not achieving complete closure on others. Snowplows with metal blades planed off some of the ridges, which then required patching with a dense mixture in the PFC. The sealed reflective cracks have continued to widen since being sealed in 1974. These sealed cracks plus the longitudinal paving joints restrict the flow of water across the pavement as observed during permeability testing.

Raveling of the pavement has continued to be a problem. The use of low penetration grade asphalt (60-70 pen) in this mix has probably contributed to the raveling problem. Normally the asphalt used in this area would be an 85-100 pen grade asphalt.

Permeability tests showed that a lower permeability existed in the traffic lane than outside the traffic lane. This result was expected since traffic will decrease the voids and likewise decrease the permeability. Results from tests using the Mu-Meter trailer unit[4] indicate almost no difference in wet and dry Mu-Meter values for this PFC (Table 3).

Figure 1. Sealed reflective cracks
(runway 16-34, Great Falls)

The 3/4-in.- (19.05-mm-) thick PFC on runway 3-31 was constructed in 1978. The PFC was applied in the fall in generally cool weather. Before the PFC was laid, the damaged cracks on the old runway were routed out and patched with an asphalt mix. The contractor, Thomas, Dean, and Hasgins, arrived at the mix design by varying the asphalt content and mix temperature in the test sections and also by using their own judgment and experience. They determined a final asphalt content of 7.2 percent, mixed at 300°F (149°C). A neoprene-rubberized asphalt (85-100 pen) was selected as the binder for this job. The aggregate was a limestone, similar to that used for runway 16-34. The gradation of the aggregate was within the recommended limits[4] except for a deficiency of material passing the No. 200 sieve. North Testing Laboratory in Montana performed the testing on the mix. The PFC mix, like the one on runway 16-34, was produced in a batch plant, placed with a conventional paver, and rolled with a steel-wheel roller.

According to airport personnel, the PFC was laid with an excess of asphalt binder that caused bleeding during construction and thus created rich spots (Figure 2). This bleeding might have been avoided by waiting for the asphalt to cool to some extent before compaction. The

Figure 2. Rich spots (runway 3-21, Great Falls)

areas that have bleeding problems cover approximately 10 percent of the PFC in the trafficked area. Although these patches do present slick spots when wet, they are spaced sufficiently so that there is no detrimental effect on PFC traction performance. The permeabilities were measured at well above the suggested 1000 ml/min minimum,[1] both in and out of the trafficked area. The results were excellent in areas where bleeding had not occurred.

At the time of the survey, raveling had occurred on runway 3-21 adjacent to the transverse joints (Figure 3). It appears that the paver screed dragged over high spots in the pavement in a few areas to produce small areas having little PFC mix (Figure 4). Some minor damage had been caused by snow removal equipment. Adjacent to the reflective cracks, minor raveling had occurred. Rubber buildup did not appear to be a problem. Mu-Meter test results indicate little difference between wet and dry Mu-Meter values on this runway. This runway handles both private and air carrier planes.

Figure 3. Raveling adjacent to transverse joints (runway 3-21, Great Falls)

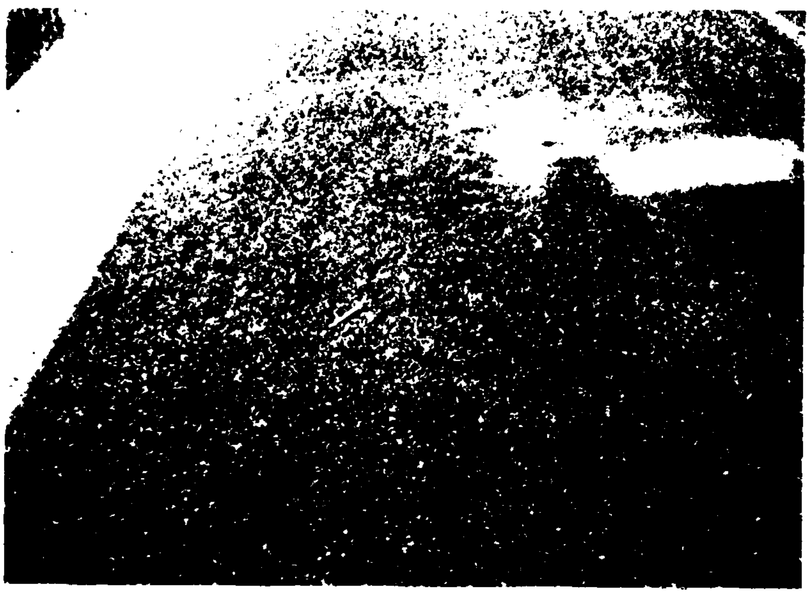

Figure 4. Loss of PFC mixture (runway 3-21, Great Falls)

GREENSBORO-HIGH POINT-WINSTON-
SALEM REGIONAL AIRPORT

A condition survey of the PFC runway at Greensboro-High Point-Winston-Salem Regional Airport was conducted in January 1980. Field permeability tests of the PFC were conducted.

At the time of the survey, the 3/4-in.- (19.04-mm-) thick PFC pavement that was constructed in September 1974 was in excellent condition. However, the last 500 ft (152.4 m) on the northern end of the runway was breaking up. As indicated by a core sample taken in this area, this problem was due to movement of the underlying asphalt mix and not to any problem with the PFC. Thompson-Arthur of North Carolina was the contractor, with the Pittsburg Testing Laboratory conducting the quality control testing. The U. S. Army Engineer Waterways Experiment Station (WES) developed the mix design using the centrifuge kerosene equivalent (CKE) test method.[7] The asphalt content was determined by using the formula: Estimated Optimum Asphalt (EOA) = $2K_c + 4.0$.[1,2,7] An asphalt content of 6.5 percent was selected along with a mixing temperature of 280°F (138°C). During construction, the temperature was increased to 300°F (149°C) with a viscosity of 270 centistokes (cSt) for a smoother laydown. A neoprene-rubberized asphalt (85-100 pen) was selected for this job. The gradation of the aggregate obtained from core samples taken in 1975[2] was within the limits of the original mix design gradation. This gradation falls within the limits recommended by the FAA.[4] The aggregate used was a granite with a specific gravity[5] of 2.82 and a Los Angeles abrasion test[6] value of 24 percent. The PFC was mixed in a batch plant, placed with a conventional paver, and rolled with two steel-wheel rollers making from two to four passes. A light tack coat was applied over a heavier 8-in.- (20.32-cm-) wide band coating sprayed on the joints of the underlying pavement to ensure a good moisture seal.

There was some damage caused by snow removal equipment and some minor stripping of the asphalt from the surface aggregate. Patchwork, when necessary, was conducted with an available state highway PFC mix. The permeabilities measured well above the 1000 ml/min minimum.[1] The lower permeability obtained in the traffic lane could be accounted for by the increased compaction of the traffic.

The results from Mu-Meter tests indicate an average difference of only 6 percent between wet and dry Mu-Meter values on the PFC. Despite a slight rubber buildup at about 1000 ± 500 ft (304.8 ± 152.4 m) from the end of the runway, the normal touchdown area for aircraft, there was no significant decrease in Mu-Meter values. Airport personnel said that at first some pilots complained of the increased tire wear, but they all appreciated the skid resistance afforded. The operations manager mentioned that ice occurred on the PFC pavement before it occurred on the other runway, a dense-graded pavement. However, the ice on the PFC pavement thawed before the ice on the dense-graded pavement.

MONROE REGIONAL AIRPORT

A condition survey of the PFC runway at Monroe Regional Airport was made in April 1980. Field permeability tests were conducted and six core samples were obtained.

The 1-in.- (2.54-cm-) thick PFC on runway 4-22 was constructed in October 1974. It overlaid a new 7-in. (17.78-cm) layer of asphalt concrete, which was placed on top of an old portland cement concrete pavement. Jenkins, Lazenby, and Associates, L. D. Ritter, and Shilstone Testing Laboratory, all from Monroe, Louisiana, were the consulting engineers, the paving contractor, and the testing laboratory, respectively, for the PFC construction. The mix design was developed by utilizing five test sections and varying the asphalt content and mixing temperature. An asphalt content of 5 percent was selected along with a mixing temperature of 250°F (121°C). This percent asphalt appears to be relatively low when compared with the asphalt content for other PFC's. This low asphalt content could have contributed to the raveling along the reflective cracks and also some raveling of the surface aggregate (Figure 5). The original gradation fell within recommended FAA limits.[4] The gradation obtained from the cored samples (Table 2) shows that there is not the required amount of coarse material (retained on the 3/8-in. (9.53-mm) sieve and larger). Aggregate wear, poor production control at

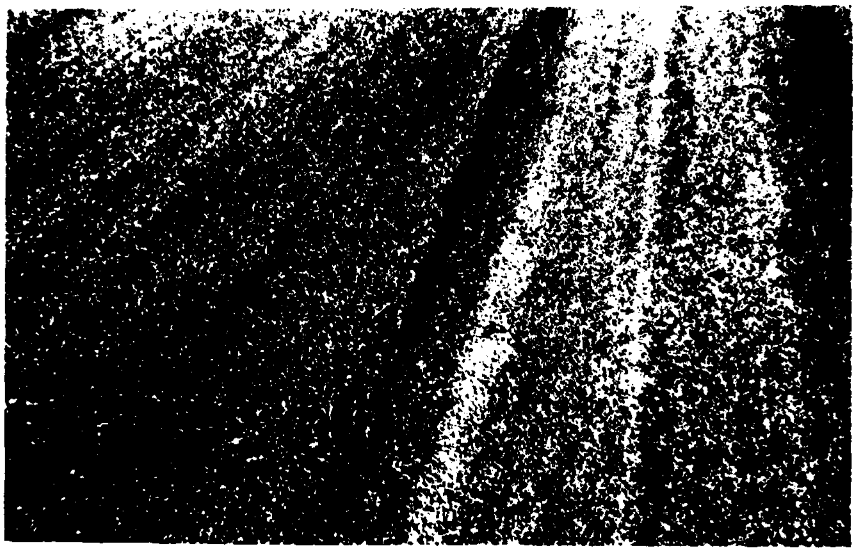

Figure 5. Raveling along reflective cracks (runway 4-22, Monroe)

the plant, or the limited amount of sample material tested could account for the difference. The aggregate used was a chert with a specific gravity[5] of 2.7 and a Los Angeles abrasion test[6] value of 23.7 percent. Prior to placing the PFC, a light tack coat was applied to the existing pavement. The PFC was mixed in a batch plant, placed with a conventional paver, and rolled with a steel-wheel roller.

The permeability measured was well above the suggested 1000 ml/min minimum.[1] At the time of this survey, there was substantial rubber buildup along the center of the runway. Since the rubber buildup was causing no wet traction problems, no immediate plans were made for removing the rubber.

The airport manager noted that there was poor surface drainage across the runway and that the longitudinal paving joints acted as small dams ponding water flowing across the runway. A deep rut caused by a flat tire on a landing aircraft ran half the length of the runway and onto a taxiway. This rut had been filled with asphalt mix. Several places on the PFC pavement had been scarified by the use of metal snowplow blades. This problem was alleviated by the use of hard rubber blades. Urea had been used for snow and ice removal, and sand had been used for traction. On one side of the runway, there had been a settlement of 2 to 3 in. (5.08 to 7.62 cm) on a section 10 ft (3.05 m) wide that extended from the edge of the pavement to the center line of the runway (Figure 6). The airport manager believed this settlement to have been caused by a failure of the old underlying portland cement concrete pavement. The airport manager also felt, as did the airport manager in Greensboro, that water on the PFC froze and thawed quicker than on conventional dense-graded mix. The pilots were satisfied with the wet traction provided by the PFC pavement.

DALLAS NAVAL AIR STATION

A condition survey of the PFC runway at the Dallas Naval Air Station was conducted in May 1980. At this time, field permeability tests were conducted on the PFC, which had been constructed in September 1971. This 5/8-in.- (15.88-mm-) thick PFC overlaid a leveling course that was placed to provide proper grade to the existing pavement.

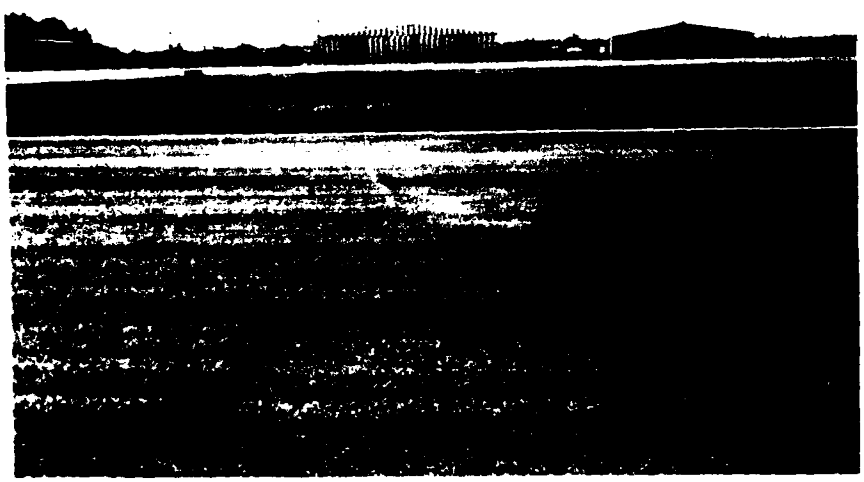

Figure 6. Failure in pavement section (runway 4-22, Monroe)

W. P. Wills, Consulting Engineers, of Dallas, Texas, designed the PFC. Uvalde Construction Company, Texas, was the paving contractor and Southwestern Laboratory, Texas, was the testing laboratory. The mix design was developed by building a test section and varying the asphalt content and mix temperature as required. An asphalt content of 6.5 percent was determined along with a mix temperature of 240°F (116°C). A low penetration asphalt (47 pen)[1] was used in the mix. The aggregate used was a basalt with a Los Angeles abrasion test[6] value of 15.4 percent. The gradation of the core samples approached the original construction specification limits. This gradation differs from most in that it is made up almost entirely of one size aggregate and contains almost no fines (5.3 percent passing No. 8 sieve). At the time of this survey, severe raveling of the surface aggregate had occurred. This raveling probably was caused to some extent by a combination of the low penetration asphalt (47 pen) used and the one size aggregate in the mix. Periodic sweeping had kept foreign object damage to a minimum. The abrasive effects of the braking aircraft plus some fuel spills had magnified the raveling problems.

A light tack coat of RS-1 was used. The PFC was mixed in a batch plant, placed with a conventional paver, and rolled with three passes by a 10-ton (9.08-metric-ton) steel-wheel roller. After the PFC had cooled for at least 2 hr, it was rolled with a pneumatic roller. This rolling probably helped seat the aggregate where the steel-wheel roller bridged over low spots.

The permeability afforded by the PFC was excellent (Table 2). The high permeability was probably attributable to a combination of the small amount of fines in the PFC and also by the large amount of surface raveling that occurred. Figure 7 shows a number of longitudinal cracks with associated raveling. Further damage was caused by snow removal equipment and also by the aircraft arresting gear (Figure 8). The PFC had been patched in spots where fuel spills had occurred.

In 1977, a 1400-ft (426.7-m) extension of the PFC was added to the northern end of the runway. The existing asphalt surface was cold-planed to permit a smooth abutment between the old PFC and the new one.

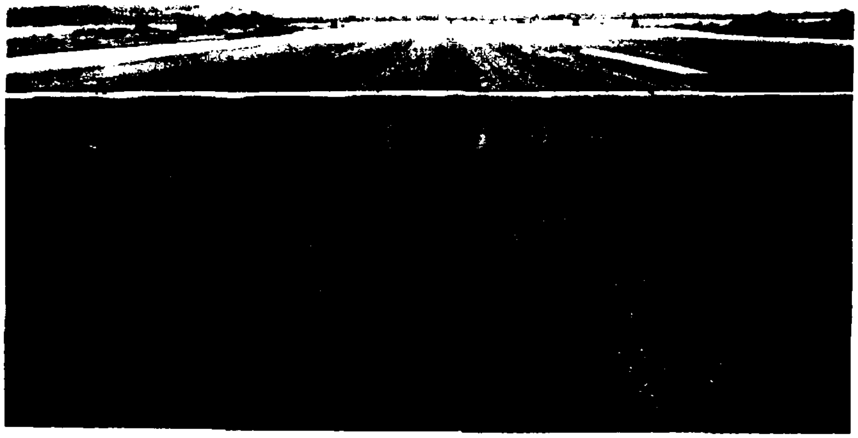

Figure 7. View of surface raveling and longitudinal paving joint (runway 17-35, Dallas)

Figure 8. Damage from arresting gear (runway 17-35, Dallas)

As in 1971, a leveling course was placed to provide the proper grade to the existing pavement. The major variations of this PFC as compared with the one constructed in 1972 are: (a) a higher penetration asphalt (60-70 pen) was used; (b) 1.5 percent hydrated lime was added to the mix for its antistripping characteristics; and (c) the gradation was adjusted to increase the amount of material passing the No. 8 and smaller sieves, with 3 percent passing the No. 200 sieve. These three changes have produced a PFC that is performing well and in excellent condition (Figure 9). Public Works Office personnel were satisfied with the performance of the PFC's.

PEASE AIR FORCE BASE

A condition survey of the PFC runway at Pease Air Force Base was made in January 1980. The 1-in.- (2.54-cm-) thick PFC at Pease Air Force Base was constructed in September 1972. Three core samples were taken from the trafficked area. Further sampling and inspection of the runway was inhibited because of aircraft operations.

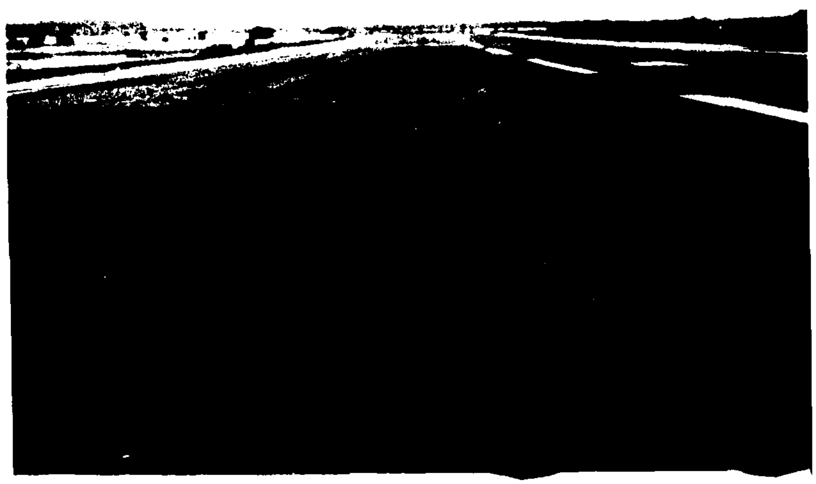

Figure 9. View of new PFC extension, old PFC in background (runway 17-35, Dallas)

The contractor was Iafola Construction Company of Portsmouth, New Hampshire, with base personnel handling the design and control testing during construction. The mix design was adjusted by varying the asphalt content and mixing temperature during the construction of the test section. An asphalt content of 5.2 percent was selected. The asphalt used was a high penetration asphalt (120-150 pen), which is normal for this region. Hydrated lime (1.5 percent) was added to the mix to prevent stripping of the aggregate and to improve the handling of the mix. The gradation of the aggregate in the original design mix and that obtained from the core samples were both within the recommended gradation limits.[4] The aggregate used was a basalt with a specific gravity[5] of 2.76 and a Los Angeles abrasion test[6] value of 13.5 percent. The mixing temperature used was 250°F (121°C). The PFC was mixed in a batch plant, applied with a conventional paver, and rolled with two to four passes by a steel-wheel roller. A leveling course had been placed over low areas on the existing pavement to provide proper grade. Prior to placing the PFC, a tack coat was applied to this leveling course. Soon after construction of the PFC, reflective cracks came through in a pattern indicative of the pavement condition prior to the leveling course.[1] In 1974, many of these reflective cracks were sealed with Petroset. The Petroset sealed the cracks, but according to base personnel, it also restricted the flow of water across these cracks.

The permeability of the PFC as determined from permeability tests was above the accepted minimum of 1000 ml/min.[1] At the time of inspection, there were some popouts (Figure 10) and several reflective cracks. However, very little raveling had occurred adjacent to these reflective cracks. Locked-wheel or 180-deg turns have not been allowed on the PFC. No significant damage attributable to snow removal equipment was noted. Urea that was used for snow and ice removal had no apparent effect on PFC performance. Some rubber buildup was observed over most of the runway, but it had not caused any skid problems. The PFC pavement on the runway was in good condition, and the base personnel were satisfied with its performance.

Figure 10. Popouts (Pease)

PORTLAND INTERNATIONAL AIRPORT, MAINE

A condition survey of the PFC runway at Portland International Airport was conducted in January 1980. During this survey, six core samples were obtained.

The 3/4-in.- (19.05-mm-) thick PFC was constructed in 1973. Blue Rock Industries of Maine was the contractor with the Maine Department of Transportation providing the design and quality control testing. The mix design was determined by using the Marshall mix design method. The Marshall method of design is not recommended for use in designing PFC pavements. The use of the CKE test[7] for determining the EOA is recommended.[1,2,8] An asphalt content of 6.5 percent was determined by using the Marshall method. The asphalt used was an AC-20 (82-85 pen) supplied from two different refiners. The mixing temperature selected was 300°F

(149°C). The asphalt was obtained from Shell and Exxon and had viscosities at 275°F (135°C) of 485 and 409 cSt, respectively. The gradation of the aggregate was within the recommended limits.[4] The gradation of the aggregate from the core samples taken was about 15 percent finer on every sieve than the original gradation, probably because of aggregate breakdown or improper quality control during construction. The aggregate used was a ledge rock with a specific gravity[5] of 2.69. Two batch plants were used to manufacture the PFC, a Cedar Rapids and a Baldwin-Lima-Hamilton. The PFC was placed with a conventional paver and rolled with a steel-wheel roller.

The permeability of the core samples from the PFC measured approximately 20 percent below the suggested 1000 ml/min minimum,[1] both in and out of traffic, when tested in the laboratory. This low permeability could probably be attributed to the high amount of material passing the finer sieves (Nos. 4-200) in the core.

At the time of survey, the pavement was in good condition with only minor damage from snow removal equipment (Figure 11). The PFC had

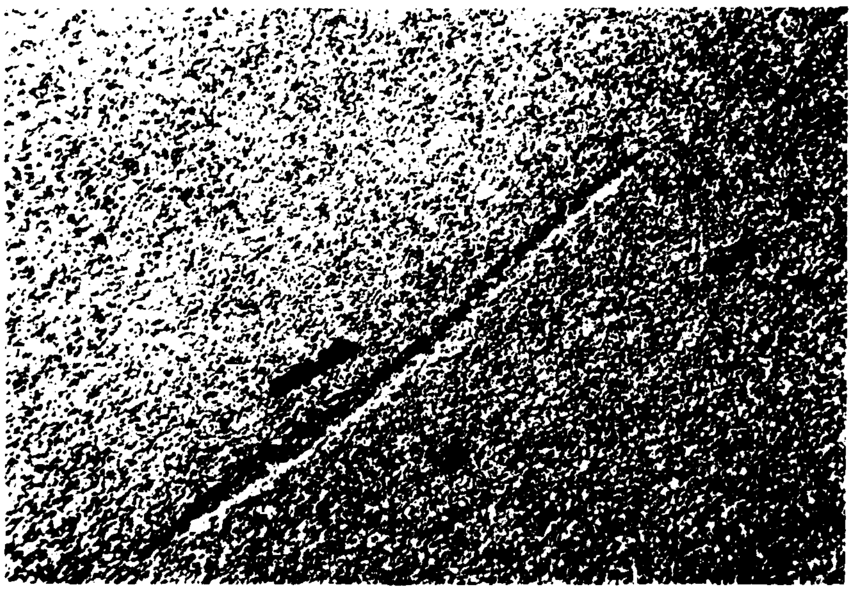

Figure 11. Surface texture and equipment damage (Portland)

not been damaged by turns at the taxiways. Longitudinal paving joints were in good condition. A few popouts and also several reflective cracks with adjacent minor raveling were noted. The minor rubber buildup posed no problem (Figure 12).

SALT LAKE CITY INTERNATIONAL AIRPORT

A condition survey of the 3/4-in.- (19.05-mm-) thick PFC runway 16L-34R at Salt Lake City was made in April 1980. The PFC pavement on runway 16L-34R, along with the PFC pavement on the parallel taxiway, was constructed in August 1972. When the PFC was constructed, an additional 1200 ft (365.8 m) of runway was added onto the northern end. The runway and the taxiway PFC's were laid directly on the old flexible pavements.

Gibbons and Reed Construction Company of Utah was the contractor. Airport personnel performed the quality control and testing of the mix. The final PFC mix design was developed by placing a test section and adjusting the mix as necessary. The asphalt used was a low penetration asphalt (60-70 pen) with 1.5 percent neoprene rubber added. The asphalt

Figure 12. Overall view of PFC runway (Portland)

content was 5.75 percent. The mixing temperature selected was 325°F (163°C) with an asphalt viscosity of 185 cSt. Minor asphalt drainage from the mix was reported during construction. The original gradation and the gradation of the cores fell within recommended limits.[4] The aggregate used was a slag with a specific gravity[5] of 3.75 and a Los Angeles abrasion test[6] value of 12 to 15 percent. This region has an average of 100 freeze-thaw cycles per year. A light tack coat of SS-1h emulsion was used. The PFC was mixed in a batch plant, applied with a conventional paver, and rolled with a steel-wheel roller.

Permeability tests were conducted on runway 16L-34R and on the parallel taxiway. These test results varied greatly because of the surface features present, such as minor surface raveling and several rich spots in the PFC.

At the time of this survey, many reflective cracks had been sealed with a tar and tire-shread compound. These sealed cracks along with several rich spots (less than 5 percent of the pavement area) in the runway restricted the flow of water (Figure 13). In at least two

Figure 13. Sealed cracks and rich spots (runway 16L-34R, Salt Lake City)

places, a failure of the pavement structure had occurred that required patches approximately 12 ft (3.66 m) wide and running the entire width of the runway (Figure 14). The runway in this area may have contributed to the failure because it is only 4 ft (1.22 m) above the water table. Damage from snow removal equipment was confined mostly to the taxiway and ramps leading to the runway (Figure 15). Warm sand and urea were being used for snow and ice removal.

SCOTT AIR FORCE BASE

A condition survey of the PFC runway at Scott Air Force Base was made in May 1980. The 3/4-in.- (19.05-mm-) thick PFC was constructed in May 1976. It was constructed on top of 6 to 8 in. (15.24 to 20.32 cm) of old asphalt concrete overlaying 6 to 8 in. (15.24 to 20.32 cm) of portland cement concrete.

Thacker Construction Company of Illinois was the contractor. The U. S. Army Corps of Engineers, Omaha District, Nebraska, handled the

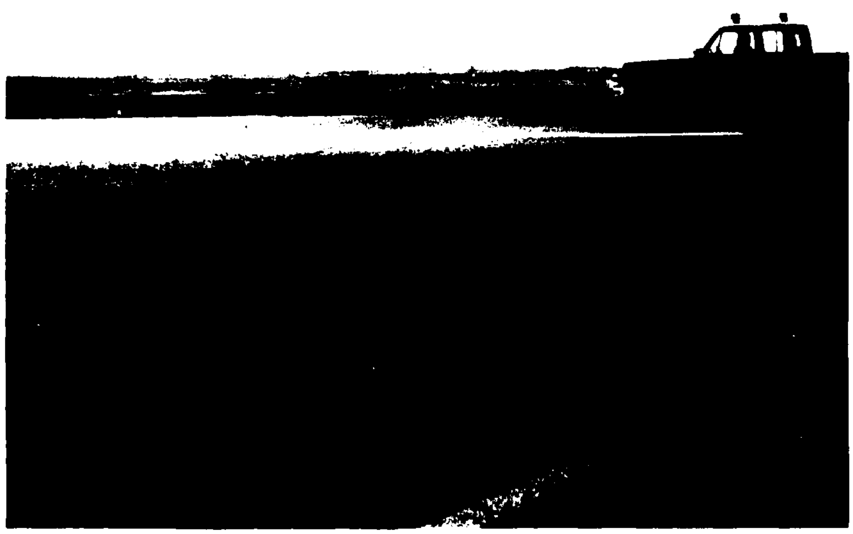

Figure 14. Patch running full width of runway (runway 16L-34R, Salt Lake City)

Figure 15. Damage from snow removal equipment (runway 16L-34R, Salt Lake City)

design and testing for the construction. The mix design was developed using the K_c factor for the CKE test method[7] and the formula, $EOA = 2K_c + 4.0$,[1,2,8] for the percent of asphalt required. Mix production began with 6.5 percent asphalt mixed at 285°F (141°C); after construction started, the mixing temperature was raised to 300°F (149°C). The binder used was a neoprene-modified asphalt consisting of an 85-100 pen grade asphalt and 1.5 percent neoprene-rubber additive. This material was blended by Husky Oil in Cody, Wyoming. The original gradation was within recommended limits.[4] The aggregate used was a blended felsite with a specific gravity[5] of 2.77 and a Los Angeles abrasion test[6] value of 18.2 percent.

According to an observation report by the WES,[9] initially the SS-1h emulsion was applied at a rate of 0.03 to 0.04 gal/sq yd (0.14 to 0.18 cu dm/sq m) and then rolled with a pneumatic roller. The tack coat was picked up by the roller tires and dropped as the buildup continued. These areas would bleed through the PFC; hence the contractor was required to remove this material with shovels before overlaying. The application rate was later increased to 0.05 gal/sq yd (0.23 cu dm/sq m), and the rolling of the tack was eliminated.

The PFC was mixed in a continuous mix plant and placed with a conventional paver. The pavement was rolled with two to four passes of a steel-wheel roller. Initially, the final pass over the PFC was made with a pneumatic roller to remove the sheen from the PFC, but this pass was discontinued because it picked up the mix and was judged unnecessary.

Permeability tests were performed on the PFC in and out of the traffic area. The permeability test results varied considerably within both areas, probably because of the varying surface features present such as rich spots and also some raveling of the surface aggregate (Figure 16). There were some isolated cracks with adjacent minor raveling (Figure 17). The PFC suffered some damage from snow removal equipment turning at the exit ramps. The rubber buildup at the time of this survey was not excessive and, according to base personnel, had caused no problems.

Figure 16. Reflective crack and view of surface condition (Scott)

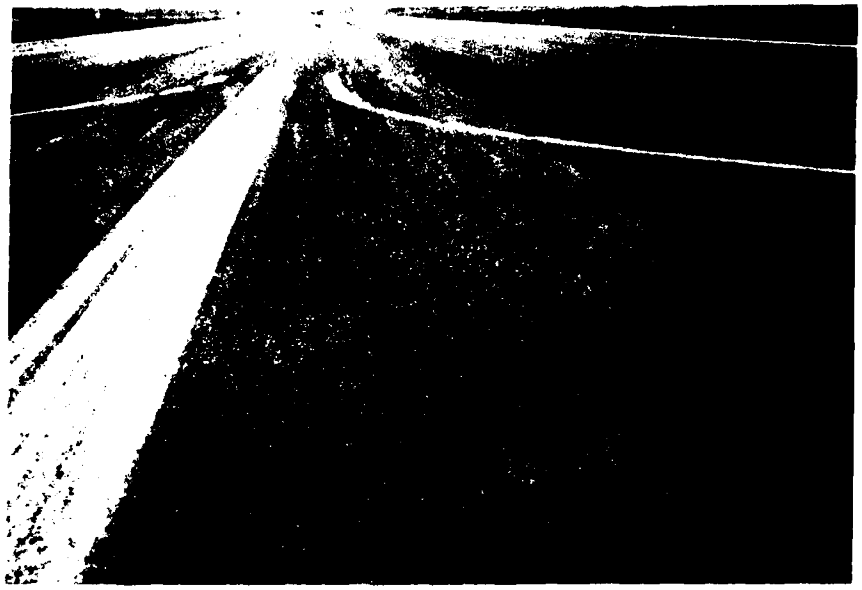

Figure 17. Reflective cracks (Scott)

Repairs have been required on the runway because of severe bulging of the pavement at points approximately 1000 ft (304.8 m) apart. Base personnel, because of the spacing of these bulges, felt that thermoheaving of the concrete underneath caused the bulging and that this thermoheaving was accentuated by the black surface of the PFC. The repair method used consisted of sawing and removing the PFC along with all the underlying material and then replacing the material removed with portland cement concrete. Overall, the runway was in good condition, and the base personnel were satisfied with its performance.

SIOUX CITY MUNICIPAL AIRPORT

A condition survey of the PFC runway 13-31 at Sioux City was conducted in May 1980. The 1-in.- (2.54-cm-) thick PFC on runway 13-31 was constructed in 1974. Permeability tests were conducted and core samples were taken from the PFC.

Brower Construction Company of Iowa was the contractor and Midwest Testing Laboratory of Iowa performed the quality control testing. Trial mixtures of PFC were prepared as described in FAA P-402.[4] The results of these drainage tests were inconclusive and a satisfactory percent asphalt could not be determined. The final mix design was developed by building a test section and varying the percent asphalt and mixing temperature to arrive at the desired PFC pavement. An asphalt content of 6.0 percent of 85-100 pen grade asphalt was selected along with a temperature of 265°F (129°C) at placement. According to the testing laboratory, a test to attempt to remove part of the test section indicated a very good bond between the PFC and the underlying asphalt pavement. The gradation of the aggregate was within recommended limits,[4] although it was on the lower side of the gradation limits. Except for the original PFC at Dallas Naval Air Station, this PFC has the least amount of fines (passing Nos. 4-200 sieves) of all PFC's surveyed. This small amount of fines may have contributed to the severe raveling of the surface aggregate over the entire runway, which existed at the time of this survey (Figure 18). The runway had been swept periodically to keep it free from loose aggregate. Airport personnel felt that the wheels on their large snowplows may be helping to loosen the aggregate.

Figure 18. Surface raveling and reflective cracks (runway 13-31, Sioux City)

A quartzite aggregate was used with a specific gravity[5] of 2.68 and a Los Angeles abrasion test[6] value of 21 percent. The PFC was mixed in a batch plant, placed with a conventional paver, and rolled with a steel-wheel roller. Large reflective cracks running both longitudinally and transversely along the runway showed severe raveling (Figure 19). According to airport personnel, the rubber buildup, which was heavy in spots, had not caused any problems (Figure 20).

The permeability tests showed a high permeability, well above the suggested minimum of 1000 ml/min.[1] This high permeability is probably due in part to the comparably small percentage of aggregate passing the smaller sieve sizes (Nos. 4-200).

A 1-in.- (2.54-cm-) thick PFC was constructed on runway 17-35 in 1977. This runway was not tested, but its performance was reported to be similar to that for runway 13-31. The mix used on runway 17-35 was similar in most respects to that used on runway 13-31 except that a lower penetration asphalt (60-70 pen versus 85-100 pen) and a slightly coarser gradation were used. In the opinion of the testing and engineering company for both PFC's constructed, the PFC on runway 17-35 has

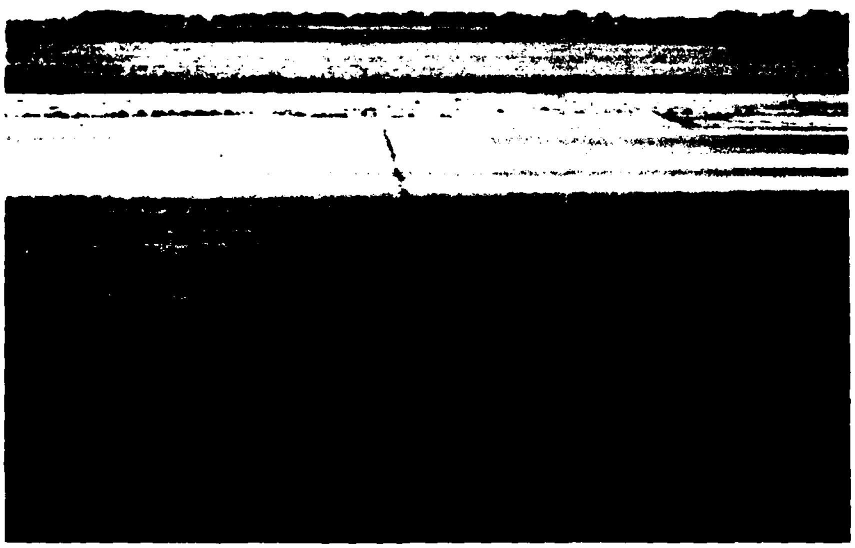

Figure 19. Reflective crack (runway 13-31, Sioux City)

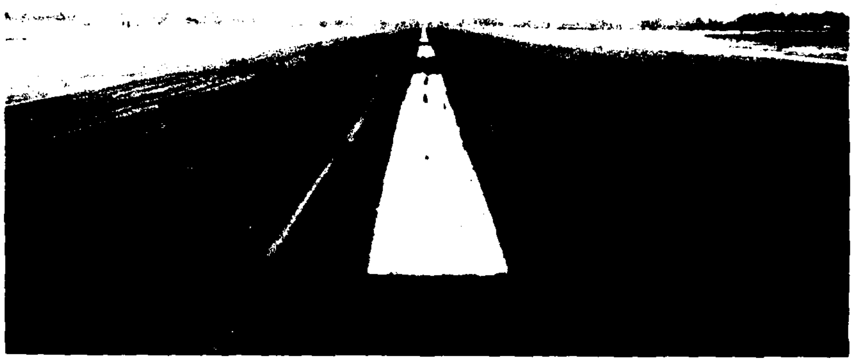

Figure 20. Overall view of PFC runway (runway 13-31, Sioux City)

experienced more loose aggregate than the PFC on runway 13-31. Shortly after construction, 0.15 gal/sq yd (0.68 cu dm/sq m) of SS-1h emulsion fog seal was applied to this runway. The purpose of the fog seal was to alleviate the raveling problem. At the time of this survey, airport personnel indicated that the seal had stabilized the raveling, that the PFC had retained its permeability, and that water had flowed from the edge of the PFC after it had rained. Both PFC's were performing well. One problem that had been reported was an increase in the amount of tire wear due to the PFC surface.

JOE FOSS FIELD, SIOUX FALLS AIRPORT

A condition survey of the PFC runway at Joe Foss Field was made in May 1980. Field permeability tests were conducted on the PFC, and six core samples were taken. The 1-in.- (2.54-cm-) thick PFC on runway 15-33 was constructed in the summer of 1979. It was laid directly over a 1-in.-(2.54-cm-) thick PFC constructed in 1971. Prior to overlay, the old PFC had raveled and had been patched in several places. The only surface preparation prior to construction of the new PFC was the application of a tack coat to the old PFC. An SS-1h sprayed at a rate of 0.1 gal/sq yd (0.45 cu dm/sq m) was used as the tack coat.

Myrl and Roy's Paving Company of Sioux Falls, South Dakota, was the contractor, and Schmitz-Kalda and Associates of Sioux Falls performed the design and testing of the PFC. The final mix design for the PFC was selected by building a test section and varying the asphalt content and the mixing temperature. An asphalt with an 85-100 pen was used. Added to the asphalt was 1.5 percent neoprene rubber and 1 oz (28.35 g) of silicon for 5000 gal (18.93 cu m) of asphalt. An asphalt content of 7.5 percent was selected along with a mixing temperature of 300°F (149°C). The original gradation of the aggregate was within recommended limits.[4] The gradation of the aggregate obtained from the core samples is also within these limits. The aggregate used was a quartzite with a specific gravity[5] of 2.65. The PFC was mixed in a batch plant, placed with a conventional paver, and rolled with four passes of a steel-wheel roller. At the time of this survey, a longitudinal crack, which ran the length of the runway, plus several transverse reflective cracks (Figure 21) were observed, but little raveling had occurred adjacent to these cracks.

The permeability tests showed a high permeability, well above the accepted minimum of 1000 ml/min.[1] The longitudinal paving joints were very noticeable and, from the excess flow of water from the permeability tests, showed that they act to inhibit the flow of water across the runway. Some of the surface aggregate, especially at the joints, appeared to have been crushed or broken during or after construction (Figure 22). The airport manager felt that the snowplows were shearing off the aggregate that protruded the farthest from the PFC. Results from Mu-Meter tests indicated little difference between wet and dry Mu-Meter values either in or out of the trafficked areas of the runway.

In warm weather, as when surveyed, the PFC appeared to be very pliable. This PFC mix used the highest percentage of asphalt by weight

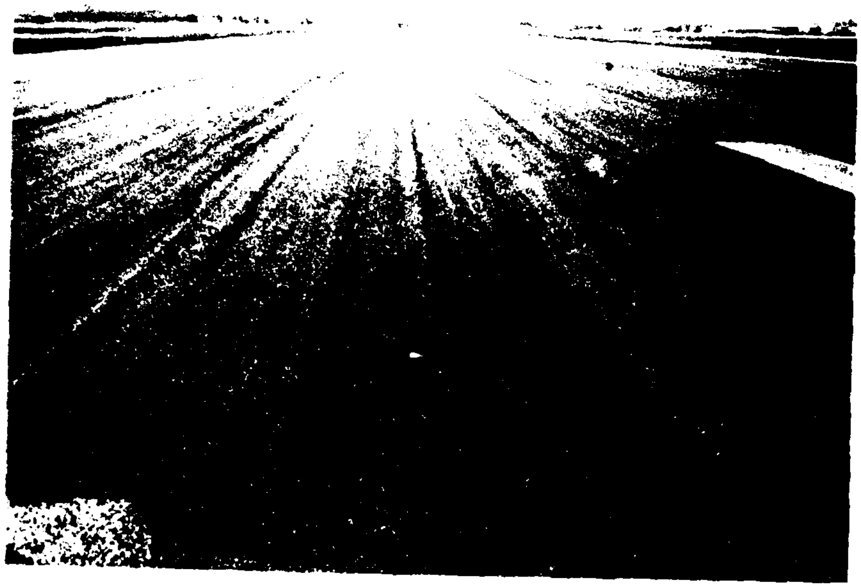

Figure 21. Reflective crack (runway 15-33, Sioux Falls)

Figure 22. Joints, rich spots, and broken aggregate (runway 15-33, Sioux Falls)

of total mix of any PFC surveyed. Because of the high asphalt content, bleeding may become a problem in the traffic areas. If bleeding does occur, this will significantly reduce the wet skid resistance.

CONCLUSIONS

The following conclusions are believed warranted based on the results of this study:

<u>a</u>. Joints in paving construction are always critical, especially with PFC's. When they restrict the flow of water as they did at Monroe, Pease Air Force Base, Salt Lake City, and Sioux Falls, they defeat the purpose of a PFC, that is, high permeability. With the thin overlays used in PFC construction, it is critical that the construction joints be correctly butted together. An improperly prepared construction joint will crack and encourage raveling adjacent to the joint. Standard maintenance procedures have been to fill these cracks with some type of emulsified asphalt. From the PFC's surveyed, it appears that experience by contractors with PFC's should enable them to construct durable joints that allow water to flow through them.

<u>b</u>. Many of the PFC pavements exhibiting raveling problems were constructed with low penetration grade asphalts. Performance results indicate that the asphalt type normally used in the area to produce dense graded asphalt mixes should be used in production of PFC mixes. The addition of neoprene rubber to the asphalt also appears to improve overall performance of PFC pavements.

<u>c</u>. Several PFC's have had problems with surface raveling. These problems in most cases have stabilized after a period of time. Probable causes for PFC's raveling could be (1) the wrong grade of asphalt used, (2) a low asphalt content, (3) PFC mix temperature too low or applied in cold weather, (4) improper mixing or coating of aggregates, and (5) stripping of the aggregate. A surface raveling problem at Sioux City was believed by airport personnel to have been caused by the PFC being placed at too low a temperature during fall construction. A fog seal was applied to this PFC to hold the aggregate in place and proved to be at least partly effective. With this solution, sufficient asphalt must be applied to hold the aggregate in place but not so much as to cause the permeability of the PFC to be reduced below the desired level.

<u>d</u>. In the opinion of airport personnel, snow and ice removal equipment has caused damage to PFC pavements. The damage observed in these surveys usually occurs at high spots or other areas where construction deficiencies occurred or in areas where the equipment has turned or maneuvered. The use of hard rubber blades has reduced the amount of damage.

<u>e</u>. The effect of freeze-thaw cycles on the PFC does not appear to be critical, probably because of the high quality of

aggregate used in the PFC's. The one case of a problem being accredited to freeze-thaw cycles occurred at Great Falls on runway 16-34. A limestone aggregate was used, but not enough data were available to determine if the limestone aggregate produced the problem.

f. Rubber buildup on the PFC can be a problem, especially at high-volume airports, but so far at the airports surveyed no attempts have been made to remove the rubber.

g. Based on the performance of the PFC's surveyed, the condition of the underlying pavement is critical. Without a good foundation pavement structure, a successful PFC cannot be constructed. At Pease Air Force Base, where cracking of the pavement existed before placement, the cracks reflected through the PFC in the same pattern. Proper control of grade and surface smoothness to get proper drainage and a uniform PFC thickness is only possible when the underlying pavement meets these requirements. Dallas Naval Air Station is an example of where the proper grade and surface smoothness were not achieved and when it rains, water ponds in low areas.

h. There has been wide variation in the methods used for mix design of PFC's. The methods used have been the Marshall mix design, the K_c factor from the CKE method, asphalt drainage tests, and engineering experience with PFC's. The optimum asphalt content determined from any of the above-mentioned methods, however, has been adjusted by constructing test sections at various asphalt contents and temperatures to determine the desired asphalt content and mix temperature.

i. At Joe Foss Field, a PFC was placed directly over an existing PFC pavement with success. No special preparation of the existing PFC was required prior to overlay.

RECOMMENDATIONS

Based on the findings of this survey, it is recommended that the following problems be studied:

a. Develop procedures to measure the functional adequacy of in-place PFC. Minimum values for both friction tests (Mu-Meter) and permeability tests (see Appendix A) would form the basis for such a measurement.

b. Identify material characteristics based on field performance that provide good performance of PFC pavements. These material characteristics should include the grade of asphalt, additives, gradation, and types of aggregates used.

c. Develop procedures for the preparation and treatment of PFC's to be overlaid. The two possible alternatives are either to overlay or to remove the old PFC.

d. Identify maintenance procedures that provide for proper replacement of damaged areas of the PFC, including construction procedures for removing and replacing the damaged PFC and also the mix design used.

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APPENDIX A: PERMEABILITY TEST

The permeability test device consists of a clear plastic standpipe (2-in. (5.08-cm) ID and 2-1/2-in. (6.35-cm) OD) with a height of 13 in. (33 cm). The device has a 1/2-in.- (12.7-mm-) thick, 4-in.- (10.16-cm-) OD collar on the bottom with a 1/4-in.- (6.35-mm-) thick sponge rubber gasket (2-in. (5.08-cm) ID and 4-in. (10.16-cm) OD) to prevent surface leakage (Figure A-1).

The results of the permeability tests are affected by the surcharge load applied to ensure contact of the standpipe and pavement surface. A surcharge load of 100 lb (444.8 N) has been satisfactorily used to ensure that the conditions of the tests are reasonably constant in this respect. Any method of supplying this surcharge is applicable, provided it is constant and is applied perpendicular to the pavement surface tested.

When the standpipe has been positioned and loaded, water is introduced into the standpipe to a level above the 10-in. (25.4-cm) mark on the side of the standpipe. The addition of water is then stopped, and the time to fall from the 10- to 5-in. (25.4- to 12.7-cm) level is measured with a stopwatch. This test is repeated three times and the average of the values is computed. The flow rate is determined from the relation $Q = VA$. Thus, for a 5-in. (12.7-cm) falling head, Q in millilitres per minute is equal to 15,436.8 divided by the time to fall in seconds. A wide range in permeability measurements can be expected, but a reasonable lower limit of permeability for newly constructed PFC pavements is 1000 ml/min.

FIELD TESTS

In the field, an open truck door or bumper-mounted bracket can be used for the reaction weight, and an extension screw can be used to apply the load. The load system should include a ball bearing or universal mechanism for self-alignment. In the field where a truck is used to react against, the truck should not be parked broadside to the wind. Wind rocking the truck will cause the load to vary and affect the results.

LABORATORY TESTS

In the laboratory, good results have been obtained by conducting the test on 6-in.- (15.24-cm-) diam specimens[1] (Figure A-2).

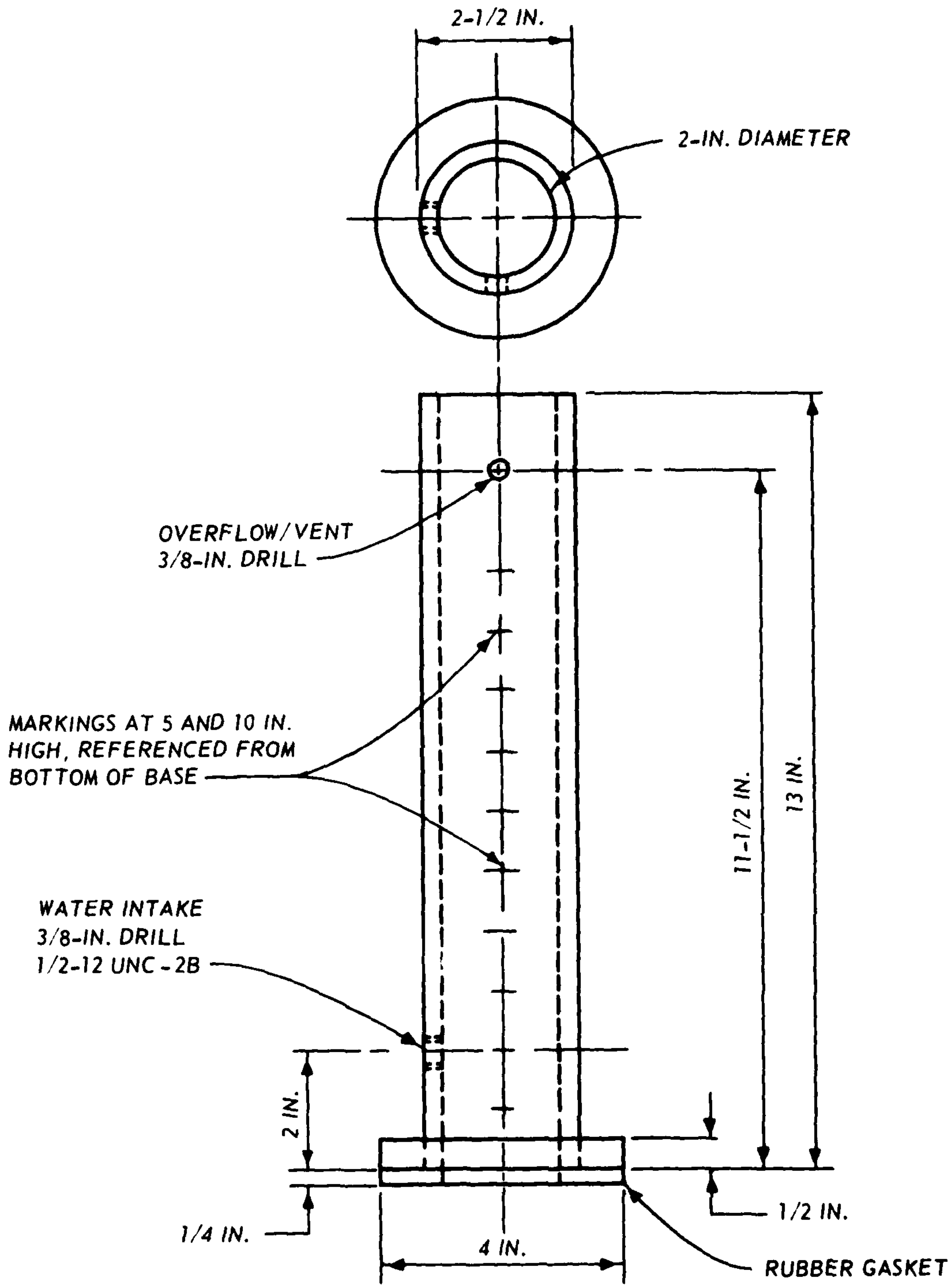

Figure A-1. Permeability device (1 in. = 2.54 cm)

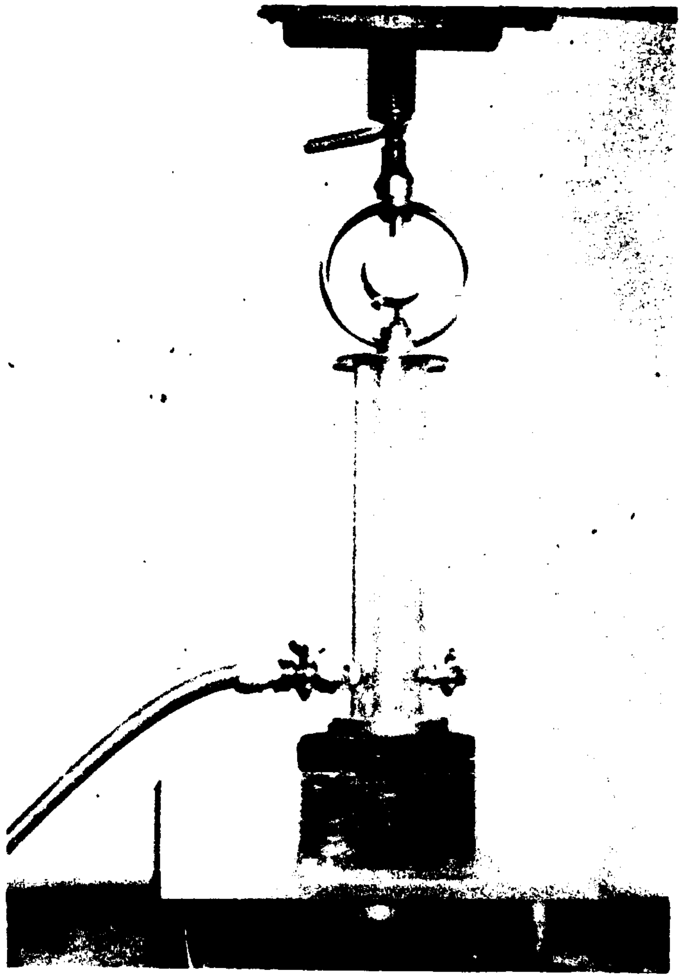

Figure A-2. Setup for laboratory permeability test